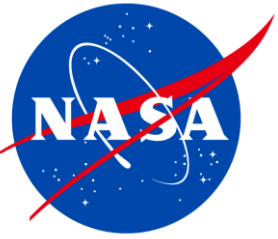


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# **Duration Uncertainty Based On Actual Performance Lessons Learned**

**Fred Kuo, Kelley Cyr and Walt Majerowicz  
IPAO**

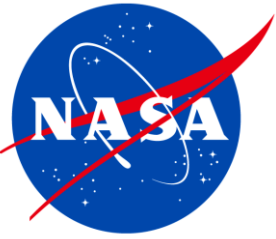
**Presented to the NASA Cost  
Symposium  
August, 2014**



# Agenda



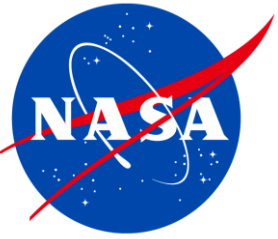
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- Introduction
  - Duration Ratio Method Summary
  - Duration Ratio Method on a NASA Project
  - Lessons Learned
  - Recommendations to NASA Scheduling Community



# Introduction

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- The authors have used the Duration Ratio Method (DRM) to characterize the schedule duration uncertainty for the schedule risk analysis (SRA) and joint confidence level (JCL) analysis of a major NASA project
  - DRM uses actual performance data at the task level of the project integrated master schedule (IMS) to develop schedule uncertainty distributions for Monte Carlo simulations
  - This presentation examines lessons learned from applying the technique to a NASA project
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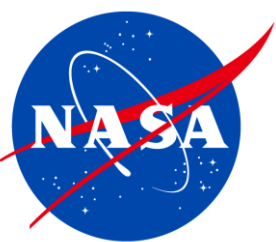


# Duration Ratio Method Summary

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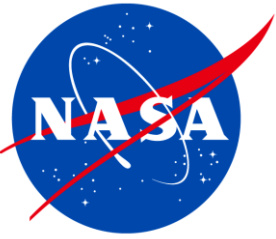
- Along with discrete risk events, schedule duration uncertainty is a significant contributor to schedule growth
- Bounding duration uncertainty is important for a sound SRA
- The project (or contractor) IMS contains an objective, performance-based source of duration uncertainty: actual and baseline durations at the task level for discrete work



# Actual vs. Baseline Durations from IMS



Task Name	Actual Duration	Baseline Duration	2012											
			J	J	A	S	O	N	D	J	F	M	A	M
<b>Develop Central / Local EM (CLEM) Subsystem</b>	<b>260 d</b>	<b>695 d</b>												
<b>CM Network / Server / DB / ODS</b>	<b>286.32 d</b>	<b>578 d</b>												
<b>Perform COTS Implementation for Central / Local CM - IDE (Inc 1)</b>	<b>129.41 d</b>	<b>293 d</b>												
Perform COTS Evaluation for Local CM - IDE (Inc 1)	19 d	19 d												
Perform COTS Evaluation for Central CM - IDE (Inc 1)	19 d	19 d												
Perform COTS Evaluation for Central / Local CM - IDE (Inc 1)	20 d	6 d												
Develop Preliminary Design for Central / Local CM - IDE (Inc 1)	35 d	25 d												
<b>Perform COTS Implementation for Central / Local CM - IDE (Inc 2)</b>	<b>126.33 d</b>	<b>311 d</b>												
Perform COTS Evaluation for Local CM - IDE (Inc 2)	19 d	19 d												
Perform COTS Evaluation for Central CM - IDE (Inc 2)	19 d	19 d												
Perform COTS Evaluation for Central / Local CM - IDE (Inc 2)	20 d	11 d												
Develop Preliminary Design for Central / Local CM - IDE (Inc 2)	46 d	44 d												
<b>Perform COTS Implementation for Central / Local Online Doc Server</b>	<b>304.54 d</b>	<b>425 d</b>												
Plan COTS Trade Studies for Local Online Doc Server	15 d	15 d												
Perform COTS Trade Studies for Local Online Doc Server	37 d	15 d												
Review COTS Trade Studies for Local Online Doc Server	24 d	10 d												
Release COTS Trade Studies for Local Online Doc Server	38 d	10 d												
Define COTS Requirements for Local Online Doc Server	19 d	15 d												
Finalize COTS Selection for Local Online Doc Server	19 d	20 d												
Plan COTS Trade Studies for Central Online Doc Server	15 d	15 d												
Perform COTS Trade Studies for Central Online Doc Server	37 d	15 d												
Review COTS Trade Studies for Central Online Doc Server	24 d	10 d												
Release COTS Trade Studies for Central Online Doc Server	38 d	10 d												
Define COTS Requirements for Central Online Doc Server	19 d	15 d												

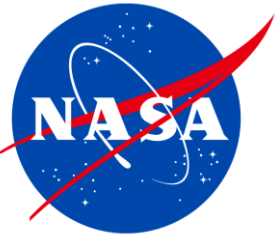


# Duration Ratio Method Formula

## Duration Ratio

	<i>Formula:</i>	<i>Example:</i>
Duration Ratio	$= \frac{\text{Actual Activity Duration}}{\text{Baseline Activity Duration}}$	$1.50 = \frac{6 \text{ days}}{4 \text{ days}}$

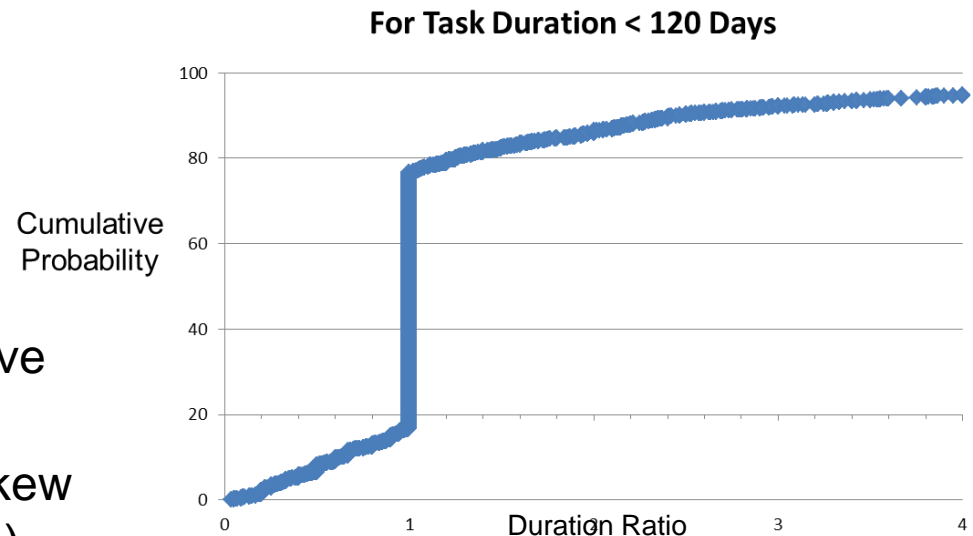
- Planned and actual task durations are factual, objective and performance-based
- Uncertainty is based on the actual project and performing organization
- Focus is on discrete activities – milestones, summary activities and level of effort-type activities are not included

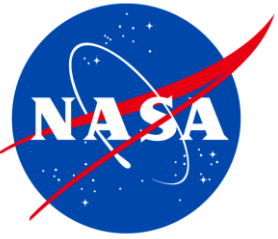


# Duration Ratio Method Steps



1. Extract completed activities from IMS file
2. Identify discrete activities: filter out summary tasks, LOE and milestones
3. Calculate Duration Ratios for activities
4. Sort in ascending order
5. Calculate percentages for S curve
6. Examine/remove outliers and anomalies that may artificially skew results (i.e. "middle 80% or 90%")
7. Segment data to reduce variance (e.g. <21 days, 21 - <50 days, >50 days)



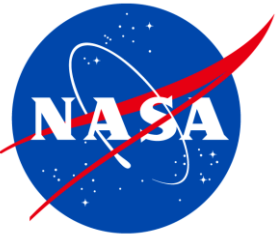


# Duration Ratio Method on a NASA Project



- DRM was used to characterize the schedule uncertainty on an Independent Program Assessment (IPA) of an actual NASA project at PDR and CDR
  - The NASA project office oversees a prime contractor on a major software system development and deployment
  - The prime has experienced significant cost, schedule, and technical difficulties resulting in multiple replans
  - At PDR the IPAO PAG used the project's schedule analysis and developed duration ratio-based schedule uncertainty
  - At CDR PAG developed a new schedule analysis model due to programmatic and technical changes and updated the schedule uncertainty with new duration ratios
    - Note: The CDR assessment became a Step 2 process late in the assessment and remains open

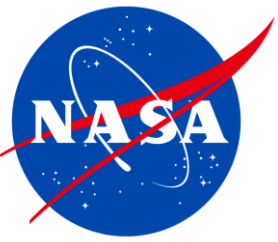




# Duration Ratio Method on a NASA Project



- At PDR, duration ratios were segmented into three categories based on actual performance since SRR, using the “middle 80-90%” results
  - < 21 days duration
  - 21 – 50 days duration
  - > 50 days duration
- At CDR, duration ratios were also segment into three categories using the “middle 80-90%” results
- Along with the discrete risks assessed by the SRB, the PDR and preliminary CDR SRA results appear on the next page



# DRM on a NASA Project: SRA Results Comparisons at PDR and CDR

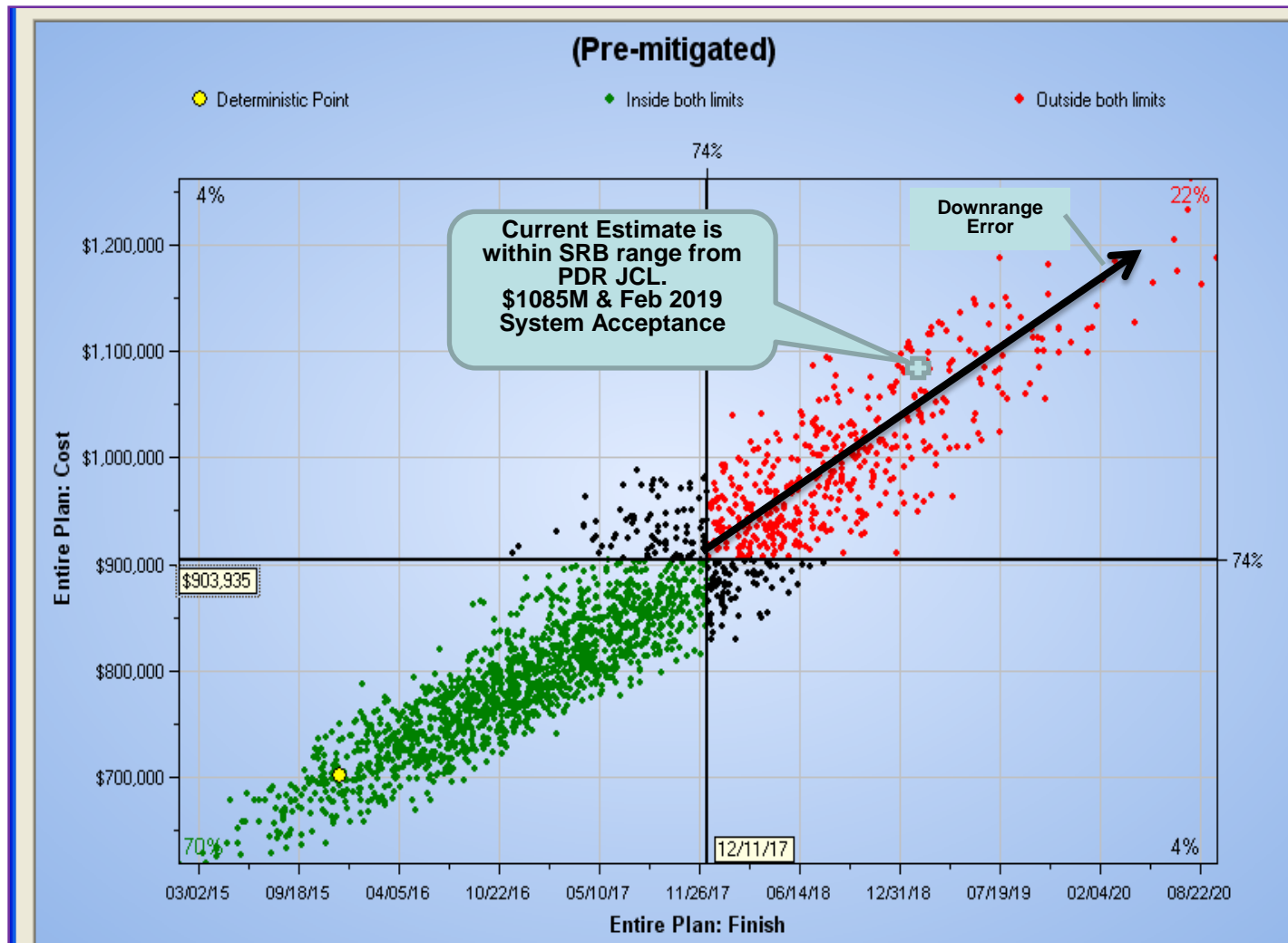
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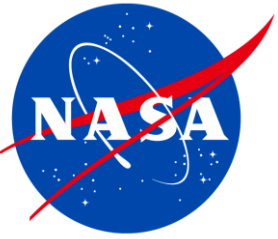


- At PDR, the System Acceptance milestone dates were:
  - Proposed Management Agreement March 2017
  - Proposed Agency Baseline Commitment June 2017
  - Prime Contractor's Current Forecast December 2015
  - Project's 70% SRA Results May 2017
  - PAG/SRB 70% SRA Results (duration ratio-based) October 2017
- At CDR, the System Acceptance milestone dates were:
  - Management Agreement March 2017
  - Agency Baseline Commitment June 2017
  - Prime Contractor's Forecast September 2016
  - PAG/SRB 70% SRA Results (duration ratio-based) February 2018
- As of June 2014, the System Acceptance milestone dates are:
  - Prime Contractor's Proposed Rebaseline May 2018
  - Project's Risk-Adjusted Estimate February 2019



# Project's Current Estimates Are Within SRB's Predicted Range

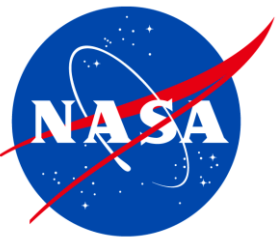




# Lessons Learned

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- Lessons Learned from applying the Duration Ratio Method on an actual NASA project IPA:
  - Remove LOE, summary and selected discrete tasks from the analysis
  - Remove outliers to reduce bias in uncertainty
  - Segment uncertainty bounds to reduce variance
  - Simplify cumulative distributions to save time
  - Use historic duration time frames that make sense
  - Early life cycle interim baselines support duration ratios for PDR
  - Duration ratio quality depends on schedule baseline control
  - Explain Duration Ratio Method to SRB members

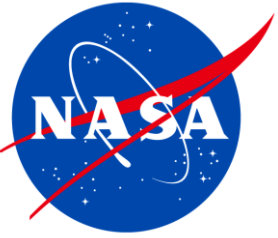


# Lesson Learned #1: Remove LOE, Summary and Selected Discrete Tasks from Analysis

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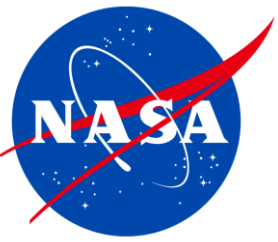
- Duration Ratios only makes sense for tasks associated with discrete, measurable work
  - LOE tasks should be removed from the analysis since actual duration = baseline planned duration and the ratio always equals 1.00
  - Summary level tasks are not needed since their lower level children tasks are already included in the analysis
  - Some routine, administrative, and non-developmental tasks may be excluded from the analysis such as documentation preparation, status meetings, and project support activities
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# Lesson Learned #2: Remove Outliers to Reduce Bias



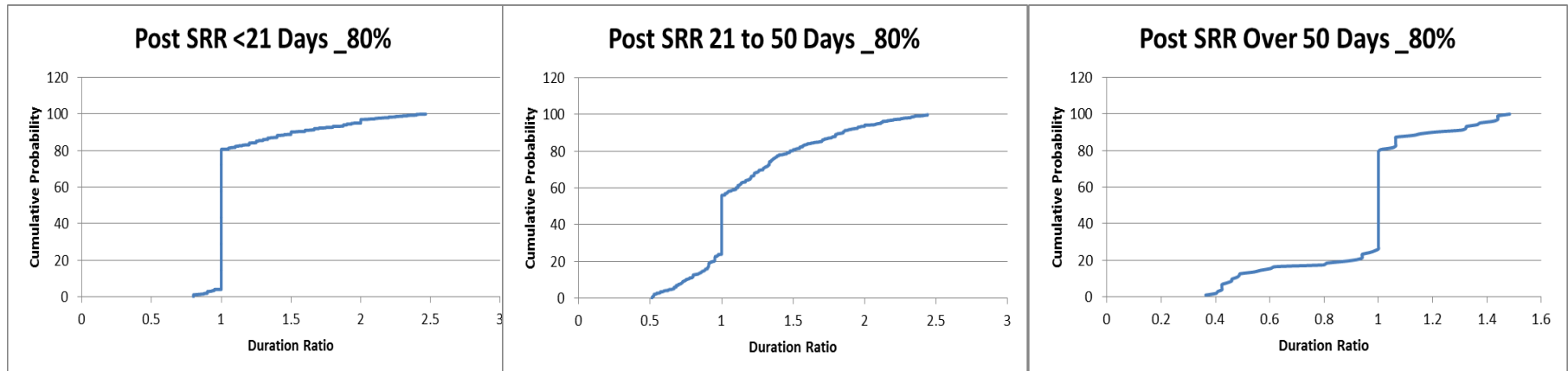
- The IMS may contain outlier duration ratios which could skew duration ratio distributions:
  - A high actual duration relative to a low baseline duration (e.g. 100 day actual / 2 baseline = 50 duration ratio)
  - A low actual duration relative to a high baseline duration (e.g. 5 day actual / 100 day baseline = .05)
- These situations should be researched with the project for accuracy, realism, or other reason and a judgment call made on retention or removal
- Narrow the data set to the “middle 80% or 90%” of the duration ratio results to normalize the results

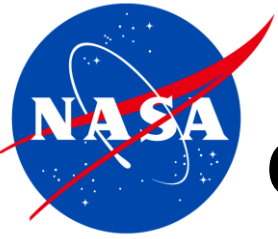


# Lesson Learned #3: Segment Uncertainty Bounds to Reduce Variance



- Schedule uncertainty can be bounded, or categorized, using duration ratio statistics
- Therefore, three categories of uncertainty bounds were developed based on middle 80% of data for baseline duration of
  - < 21 Days
  - 21 – 50 Days
  - > 50 Days

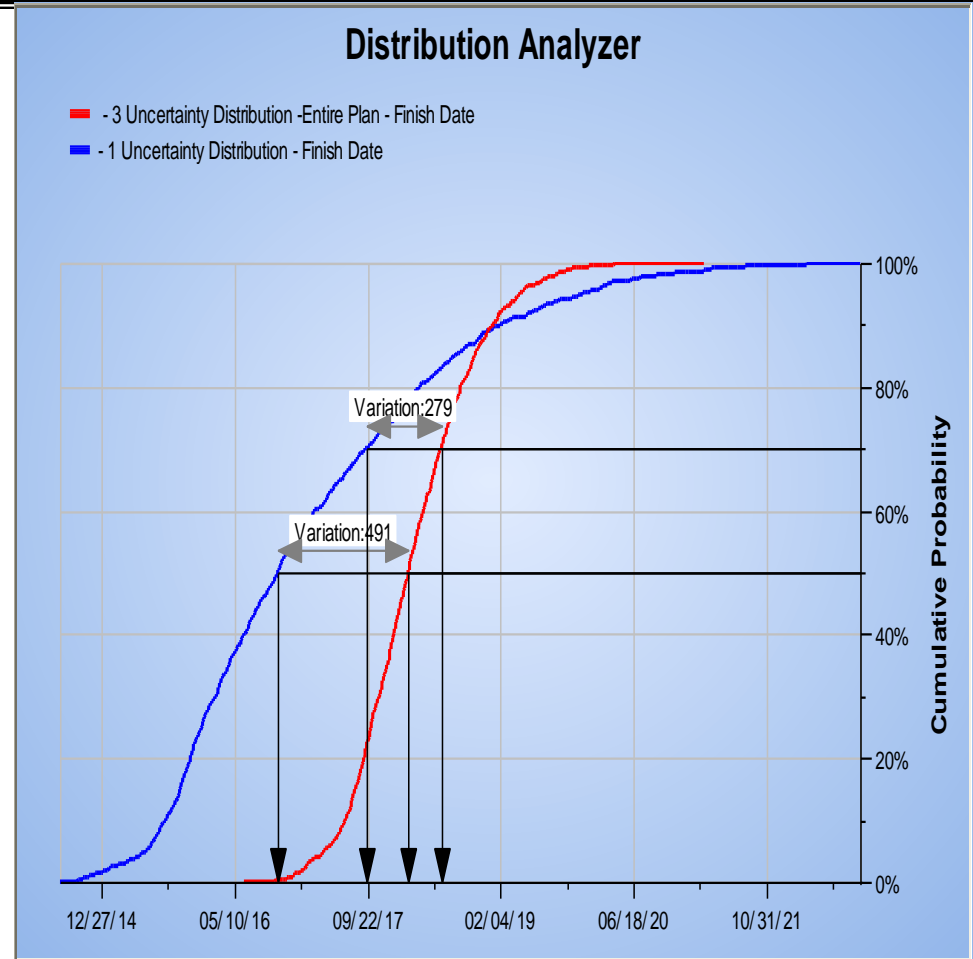




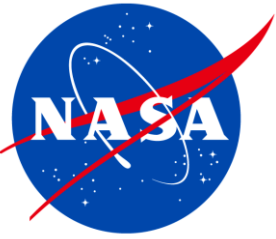
# Comparing Uncertainty Distributions



- Sample results comparing uncertainty distributions using:
  - One uncertainty distribution
  - 3 segmented uncertainty distributions
- Segmentation of uncertainty bounds reduces variance
- Evaluate alternative ways of segmenting durations and Duration Ratios: WBS, phase, element or subsystem, integration & test, etc.



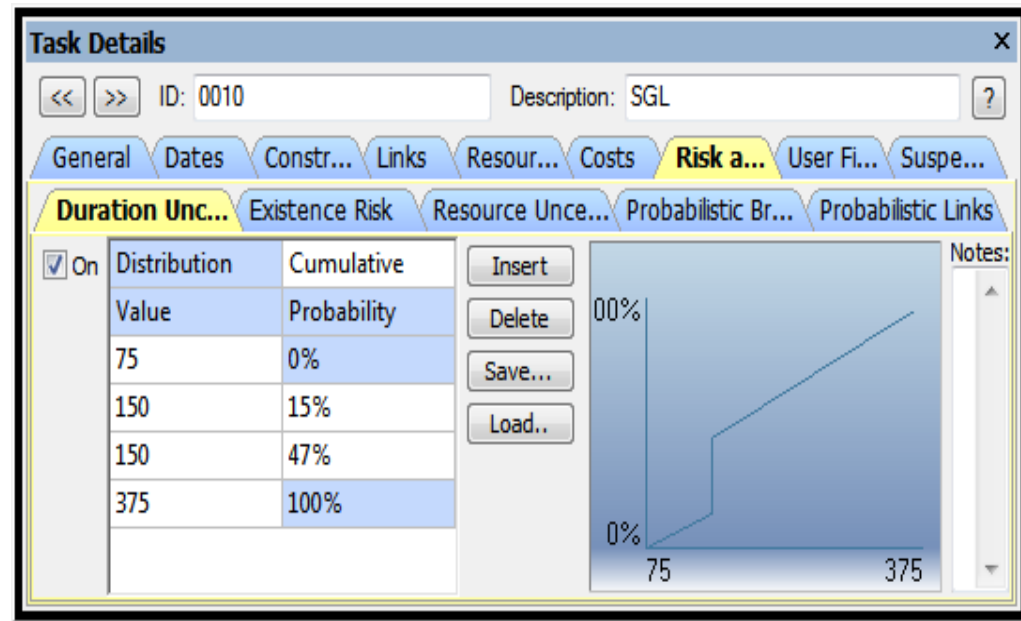


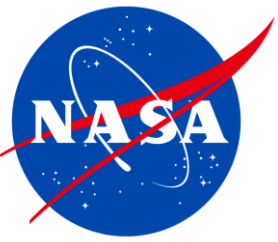


# Lesson Learned #4: Simplify Cumulative Distributions to Save Time



- Primavera Risk Analysis (PRA), allows user to input uncertainty as a cumulative distribution function (CDF) as well as some pre-defined probability distribution functions (PDFs)
- Since IMS based duration uncertainty does not conform to any known PDFs, one can only work with tools that allow user to input CDFs
- Simplifying duration uncertainty with simple 4 point ranges can save time in preparing the SRA



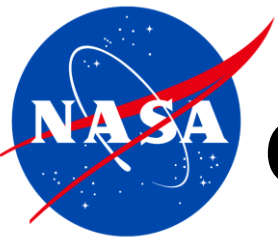


# Lesson Learned #5: Use Historic Duration Time Frames That Make Sense

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- Analysts should examine the factors that affected the schedule so far to identify whether the entire duration history or selected segments best represent duration uncertainty in the future
  - Factors to examine include: realism of schedule estimates, configuration changes, management changes, productivity assumptions, realized risks, or major replans/rebaselines
  - Also consider phase transitions. For example, actual schedule performance in manufacturing may or may not be an appropriate basis for testing phase schedule uncertainty
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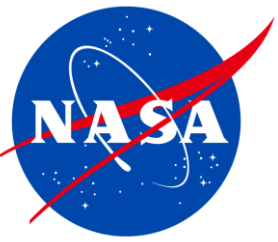


# Lesson Learned #6: Early Life Cycle Interim Baselines Support Duration Ratios for PDR

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- While NPR 7120.5E requires an IMS baseline at PDR, actual vs. baseline duration history may be available prior to PDR when:
  - The project establishes interim schedule baselines prior to PDR (e.g. Goddard requires a formulation schedule baseline at MCR)
  - Prime contract-driven projects that begin in Phase A or B normally require an earned value baseline (and supporting schedule baseline) at IBR

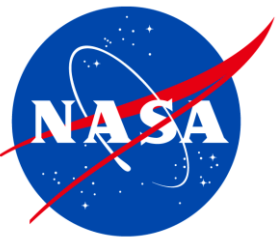


# Lesson Learned #7: Duration Ratio Quality Depends on Schedule Baseline Control

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- Baseline integrity must be maintained at the task level of the IMS for credible duration ratios
- Organizations (NASA centers, contractors, universities) may have different processes for controlling the schedule baseline – or none at all
- Schedule analysts must understand schedule baseline control methods as part of independent schedule assessment
- Effect of replans/rebaselines

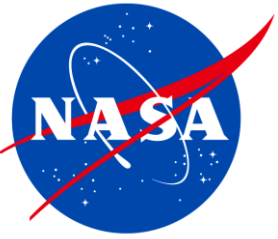


# Lesson Learned #8: Explain Duration Ratio Method to SRB Members

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- Explain to SRB members the difference between the effect of duration uncertainty and impact of discrete risk events on the SRA results to avoid “double-counting” of risk



# Recommendations To NASA Scheduling Community

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- NASA to establish an IMS data repository similar to the ONCE database.
- Conduct or fund research on schedule duration ratio across multiple projects and life cycle phases to establish realistic 4-point uncertainty distributions.